Biological responses to trauma and the development of intrusive memories: an analog study with the trauma film paradigm

Chou, Chia-Ying ; La Marca, Roberto ; Steptoe, Andrew ; Brewin, Chris R

Abstract: Evidence suggests that previous trauma reduces the cortisol response to subsequent stressors. We examined the relation of this response to intrusive memory, and the potential moderating roles of sympathetic reactions. Pre-existing trauma-related factors and the cardiac defense response were assessed before 58 healthy participants viewed a trauma film. Salivary cortisol and alpha-amylase (sAA) were collected pre-, peri- and post-film. Intrusive memories about the film were recorded for a week. Cortisol increased whereas sAA decreased after the film. Those with more recent traumatic experiences and greater subclinical PTSD symptoms had lower cortisol concentration post-film. Lower cortisol levels predicted greater vividness of intrusions. Positive correlations between cortisol and the frequency of intrusion were only present among individuals with more sympathetic activations. These findings suggest the contribution of insufficient cortisol secretion to over-consolidation of traumatic memory, and highlight the variation attributable to individual differences and different memory characteristics.

DOI: https://doi.org/10.1016/j.biopsycho.2014.08.002

Biological Psychology 103 (2014) 135–143

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Biological responses to trauma and the development of intrusive memories: An analog study with the trauma film paradigm

Chia-Ying Chou[a], Roberto La Marca[b,c], Andrew Steptoe[c], Chris R. Brewin[a,*]

[a] Clinical, Educational and Health Psychology, University College London, Gower Street, London WC1E 6BT, UK
[b] Clinical Psychology and Psychotherapy, Psychology Institute, University of Zurich, Binzmühlestrasse 14/Box 26, CH-8050 Zurich, Switzerland
[c] Institute of Epidemiology and Health Care, University College London, Gower Street, London WC1E 6BT, UK

ARTICLE INFO

Article history:
Received 18 November 2013
Accepted 7 August 2014
Available online 20 August 2014

Keywords:
Cortisol
Trauma film
Intrusions
Alpha-amylase
Cardiovascular defense response
Posttraumatic stress disorder

ABSTRACT

Evidence suggests that previous trauma reduces the cortisol response to subsequent stressors. We examined the relation of this response to intrusive memory, and the potential moderating roles of sympathetic reactions. Pre-existing trauma-related factors and the cardiac defense response were assessed before 58 healthy participants viewed a trauma film. Salivary cortisol and alpha-amylase (sAA) were collected pre-, peri- and post-film. Intrusive memories about the film were recorded for a week. Cortisol increased whereas sAA decreased after the film. Those with more recent traumatic experiences and greater subclinical PTSD symptoms had lower cortisol concentration post-film. Lower cortisol levels predicted greater vividness of intrusions. Positive correlations between cortisol and the frequency of intrusion were only present among individuals with more sympathetic activations. These findings suggest the contribution of insufficient cortisol secretion to over-consolidation of traumatic memory, and highlight the variation attributable to individual differences and different memory characteristics.

1. Biological responses to trauma and the development of intrusive memories

Cortisol is stress-reactive and influences brain regions involved in memory processing (Bowirrat et al., 2010). It has therefore been widely studied in the context of posttraumatic stress disorder (PTSD; APA, 1994). Findings regarding the influences of trauma and PTSD on resting cortisol levels have been inconsistent (Klaassens, Giltay, Cuijpers, van Veen, & Zitman, 2012). However, prior traumas have been shown to have attenuating effects on the cortisol response to a new traumatic stressor (Delahanty, Raimonde, Spoonster, & Cullado, 2003; Ehring, Ehlers, Cleare, & Glucksman, 2008; Resnick, Yehuda, Pitman, & Foy, 1995). In one study, low absolute cortisol levels after the new trauma mediated the association between prior traumatic history and later PTSD symptoms associated with the new trauma (Delahanty et al., 2003).

In terms of the effect of cortisol on memory, a meta-analysis suggested that while cortisol showed slightly positive effects on recall, studies adopting recognition tasks have reported adverse effects (Het, Ramlow, & Wolf, 2005). Echoing the latter, lower absolute cortisol levels immediately after accidents have been found among individuals who later develop PTSD and intrusive memories (Delahanty, Raimonde, & Spoonster, 2000; McFarlane, Atchison, & Yehuda, 1997). Consistent with this, insufficient cortisol secretion in the early aftermath of trauma and the related failure to down-regulate catecholamines have been hypothesized to cause over-consolidation of traumatic memories in PTSD and hence lead to intrusive memory symptoms (Yehuda & Harvey, 1997). However, inconsistent results have been reported (e.g., van Zuiden, Kavelaars, Geuze, Olff, & Heijnen, 2013).

Because in real-life situations there may be hard-to-measure complications such as the severity and nature of trauma, we adopted the trauma film paradigm (Holmes & Bourne, 2008; Lazarus, Opton, Nomikos, & Rankin, 1965) to examine the above-mentioned hypothesis and to clarify the correlations between prior trauma, cortisol level, and the development of intrusive memories. We investigated whether prior trauma would predict less cortisol secretion among healthy individuals in response to a traumatic film, and whether a lower absolute cortisol level would in turn predict the development of intrusive memories of the film. We also investigated the influence of pre-existing traits, such as dissociation, which have been linked with decreased physiological activation in response to traumatic stimuli (Lanius et al., 2010). Significant negative associations between previous traumas, preexisting trait dissociation, and cortisol concentration were predicted; in turn,

* Corresponding author. Tel.: +44 0207 679 5927; fax: +44 0207 619 1989.
E-mail addresses: c.brewin@ucl.ac.uk, ucjtcrb@ucl.ac.uk (C.R. Brewin).

http://dx.doi.org/10.1016/j.biopsycho.2014.08.002

a lower cortisol concentration was hypothesized to predict more frequent and vivid intrusive memories of the film.

Finally, we investigated potential moderators of the association between cortisol levels and intrusive memories. As sympathetic nervous system (SNS) activation has been suggested to moderate cortisol's effect on memory (Roozendaal, Okuda, de Quervain, & McGaugh, 2006; Roozendaal, Quirarte, & McGaugh, 2002), two factors related to the SNS activation were examined. First, salivary alpha-amylase (sAA) was used to index its possible effects (Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004). We predicted that cortisol and sAA would interact in a synergistic fashion to predict the number and vividness of intrusive memories.

The second moderator we investigated was the cardiac defense response (CDR; Eves & Gruzelier, 1984; Turpin & Siddle, 1978), which is a heart rate (HR) response to a sudden onset of loud noise. While almost everyone shows an increase of HR after the loud noise, a group of individuals (i.e., Accelerators) showing a secondary HR increase without any further external stimulus has been identified. The assessment of CDR has been established through careful examination of its measurement and reliability (Eves & Gruzelier, 1984; Vila, Fernández, & Godoy, 1992). Accelerators have been suggested to be more prone to adopt extreme coping strategies and to initiate a fight/flight response (Fernández & Vila, 1989). Moreover, they have been shown to have stronger anxiety traits, and greater vulnerability to anxiety disorders (Delgado et al., 2009; López, Poy, Pastor, Segarra, & Moltó, 2009; Richards & Eves, 1991; Robles Ortega, Marfil, & Reyes del Paso, 1995; Ruiz-Padial, Mata, Rodríguez, Fernández, & Vila, 2005). In assessing CDR, we expected greater vulnerability toward the development of intrusive memories among the Accelerators. Specifically, we predicted higher frequency and vividness of intrusive memory among Accelerators than Decelerators. Moreover, we expected a stronger inverse association between cortisol levels and intrusive memory among the Accelerators, compared to the Decelerators.

2. Methods

2.1. Participants

The current article reports the neuroendocrinological data from a larger study (Chou, La Marca, Steptoe, & Brewin, 2014). All procedures were approved by the Research Ethics Committee at University College London (UCL). Non-smoking native English speakers aged between 18 and 40, without any major physical or mental illnesses, and with a body mass index (BMI) range of 17.5–30 were recruited through a website recruiting UCL students and the general public in London to take part in psychological studies. Volunteers were sent a detailed information sheet about the study and screening questions via email after their first contact with the researcher. Individuals who reported having been diagnosed with or having received treatments for any mental disorders were excluded. Additionally, those who were taking medications or contraceptives, and those with cardiovascular or other significant physiological illnesses were not eligible for the study. Because the study contained graphic footages from car accidents, individuals who had experienced/witnessed, had close others seriously injured/died in road traffic accidents, or with a history of any mental disorders were also not eligible.

Volunteers who fulfilled the inclusion and exclusion criteria read through the information sheet again and asked questions before a consent form was signed at the beginning of the study. Eighty-seven completed the study. They were paid £15 as a reward for participation at the end. Only the 64 participants taking part in the afternoon (i.e., 1:30 p.m. to 6 p.m.) were included in this analysis in order to control for the circadian fluctuations of cortisol and sAA (Nater, Rohleder, Schlotz, Ehlert, & Kirschbaum, 2007). Among them, six were excluded due to procedural failures (e.g., contaminated the saliva samples, experienced actual traumatic or stressful events between the two experimental sessions), resulting in a final sample size of N = 58 (male = 32; ages between 18 and 37, $M = 24.16$, $SD = 4.22$).

2.2. Psychophysiological data acquisition

The Actiwave Cardio system (Camntech, Cambridge, UK) was used with two disposable electrodes (Blue Sensor SP; Ambu, Denmark) attached to the participants' chests to collect electrocardiography (ECG) signals. Signals were sampled continuously at 512 Hz, with resolution nine bits and no notch filter.

Salivary cortisol and sAA were collected by chewing salivettes (Sarstedt, Leicester, UK) for 2 min. Samples were stored at −20 °C before the biochemical analysis. After thawing, saliva was centrifuged at 3000 rpm for 5 min before free cortisol and sAA were analyzed using an immuno-assay with time-resolved fluorescence detection (Dressendörfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992). Inter- and intra-assay variance were both lower than 5% for cortisol, and both lower than 6% for sAA.

2.3. Psychophysiological reactivity test

A psychophysiological reactivity test (Eves & Gruzelier, 1984; López et al., 2009; Turpin & Siddle, 1978) was conducted to assess the CDR. Participants were told that the aim was to examine the effect of sound on relaxation and therefore an unexpected loud noise might be played, although the only thing they needed to do was try to relax. A 6-min resting period was given with a white noise (500 ms, 110 dB and instantaneous risetime) presented through headphones at the end followed by an 80-s ECG recording.

2.4. Trauma film viewing and intrusion diary

A 13 min–40 s trauma film (Holmes, Brewin, & Hennessy, 2004) was presented on a 28.5 cm × 40 cm computer monitor with the sound played through headphones. The film consists of five scenes of different real-life car accidents containing horrific images of emergency service personnel extracting trapped victims and dead bodies, injured individuals screaming, and body parts among vehicle wreckage. Before each scene, a brief narration (voiceover without images) introducing the context of the accident and background of the victims was played. Participants were asked to watch the film closely and imagine themselves being present and witnessing the occurrences first-hand. The researcher was present during the film viewing to ensure that all participants watched the film in full. In rare cases when participants looked away, reminders were given to return their attention to the film.

An intrusion diary was used to record the intrusions for 7 days after the film. Intrusion was defined as 'unintended and spontaneous, rather than deliberate, memories/thoughts/images about the film that easily capture attention and may interfere with ongoing activities'. Participants were asked to note the timing, give a brief description of every intrusion, and specify whether it took the form of images, thoughts, or a mixture of both. They were advised to carry the diary with them to record each occurrence as soon as possible, and to avoid retrospective completion. A text message was sent at 9 p.m. each day as a reminder to complete the diary. Participants reviewed their diary with the researcher when they returned to the laboratory on the 8th day. A self-rating of compliance (0 = very unreliable, 10 = very reliable) was then performed. The frequency of intrusive images was determined by summing up the numbers of pure imagery and mixed intrusions over the week, excluding any pure intrusive thoughts. Participants rated each intrusive image for vividness (0 = not at all, 10 = extremely) and these ratings were averaged.

2.5. Subclinical symptom, psychological trait, and state measures

2.5.1. Post-traumatic Stress Diagnostic Scale (PDS)

The PDS (Foa, 1995) is a 49-item questionnaire of traumatic experiences and PTSD symptoms. We used this scale to assess subclinical PTSD symptoms. The first section presents a checklist of different types of trauma. The second section identifies the one, among the selected events in the first section, which is the most troublesome and then asks about the elapsed time and questions for Criterion A for PTSD in DSM-IV (APA, 1994) based on the specified event. In the third and fourth sections, Criteria B, C, D, and E for PTSD are rated also based on the specified event. PTSD symptom severity is indicated by the sum of the items for Criteria B, C, and D. The scores range between 0 and 51, with 0–10 indicating mild distress, 11–20 indicating moderate distress, 21–35 indicating moderate to severe distress, and 36–51 indicating severe distress. The validity of the PDS (Foa, Cashman, Jaycox, & Perry, 1997) has been supported by good diagnostic agreement with the Structured Clinical Interview for DSM-III-R (Spitzer, Williams, Gibbon, & First, 1990).

2.5.2. State Trait Anxiety Inventory (STAI)

The STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is a self-report scale of which the first subscale measures state and the second measures trait anxiety. They each have 20 items, and anxiety levels are indicated by the sum of all items. The scores range between 20 and 80, with higher scores indicating greater anxiety. The validity of the STAI has been supported by its ability to discriminate high vs. low stress situations and by agreement with other anxiety assessment tools (Metzger, 1976; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1989). Satisfactory reliability was found in the current sample (Cronbach's α ranged between .94 and .96).

2.5.3. Dissociative Experiences Scale (DES-II)

The DES-II (Carlson & Putnam, 1993) is a 28-item questionnaire designed to examine trait-like dissociation. It is composed of three aspects: Amnesia (e.g., finding oneself in a place with no idea how one got there), depersonalization-derealization (e.g., feeling one's body does not seem to belong to one's self), and absorption (e.g., finding oneself so involved in a fantasy or daydream that it feels as though it were really happening). The percentage of time (0–100%) that one is engaged in each experience in daily life is rated. Trait dissociation was indicated by

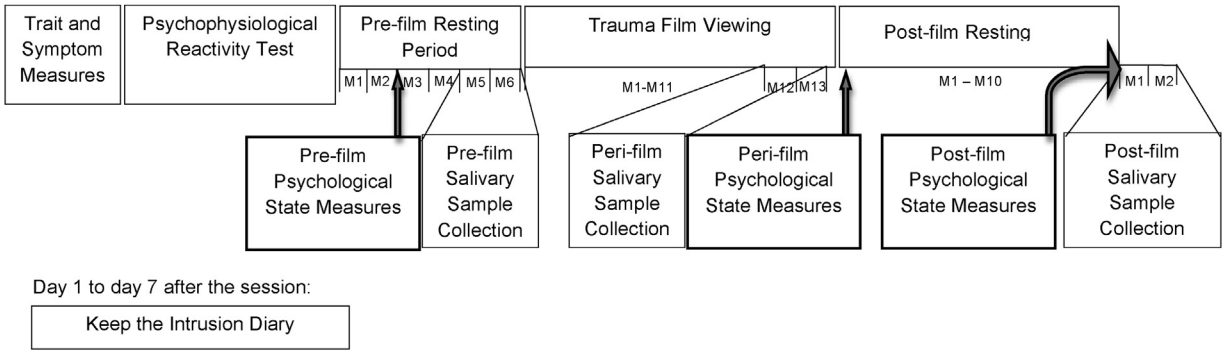

Fig. 1. Timeline of the procedures note. M1 = the first minute; M2 = the second minute; M3 = the third minute; and so on.

averaging the percentage scores with higher scores indicating greater dissociation. Evidence suggesting good validity of the DES has been found (Dubester & Braun, 1995) as well as satisfactory reliability in the current sample (Cronbach's $\alpha = .94$).

2.5.4. Dissociative State Scale (DSS)

The DSS (adapted from Bremner et al., 1998) is a 19-item self-report measurement of state dissociation. The areas covered include depersonalisation, derealisation, and amnesia. For each item, participants are required to rate on a five-point scale anchored with 0 (not at all) and 4 (extremely) based on their feelings at the particular moment when they are given the measure. The level of state dissociation was indicated by the sum of all items. The scores range between 0 and 76, with higher scores indicating more dissociation. Satisfactory reliability was found in the current sample (Cronbach's α ranged between .86 and .92). Validity has been supported by the findings that healthy participants scored lower than PTSD patients (Bremner et al., 1998).

2.5.5. Fear rating scale

The fear rating scale is an 11-point visual analog scale (0 = not at all, 10 = extremely) with higher scores indicating stronger feelings of fear at a given moment.

2.6. Procedures

All participants were asked to be free of caffeine, alcohol and any medication 24 h before testing. As shown in Fig. 1, trait and subclinical symptom measures were administered at the beginning before participants were fitted with the ECG electrodes and introduced to the psychophysiological reactivity test. Next, participants were reassured that no more sudden noise would be delivered and were given a 6-min pre-film resting period. No task was given in the first 2 min; the pre-film psychological state measures (i.e., state anxiety, state dissociation, and fear) were administered at the third minute; and the pre-film saliva sample was collected during the last 2 min of this period. The trauma film was then shown with the peri-film saliva sample collected at the beginning of the final scene (starting from the 12th minute of the film). After the film, a 10-min post-film resting period was given, with the peri- and post-film psychological state measures given at the very beginning and very end respectively. The post-film saliva sample was collected at the end of this period. The usage of the intrusion diary was then introduced. Starting in the evening after the testing, a text message was sent at 9 p.m. daily to remind the participants to check the completion for that particular day. On the 8th day, the diary was returned and a careful debrief was given.

2.7. Analytic strategy

All statistical analyses were performed with SPSS version 18 (SPSS Inc, Chicago, IL, USA). Scores greater than 3 standard deviations above the mean were changed to one unit larger than the next most extreme score in the given variable, whereas scores smaller than 3 standard deviations below the mean were changed to one unit smaller than the next most extreme score (Chou et al., 2014; Holmes et al., 2004; Tabachnick & Fidell, 1996). The variables and numbers of such cases were: pre- ($n = 1$), peri- ($n = 1$), and post-film cortisol levels ($n = 1$), pre-film sAA level ($n = 1$), trait dissociation ($n = 2$), pre-film state anxiety ($n = 1$), pre- ($n = 2$), and peri-film state dissociation ($n = 2$), and the frequency of intrusion ($n = 1$). Normality of distribution was examined by dividing the absolute values of skewness by the standard error of skewness. Variables with values larger than 3 from this calculation were square root transformed.

Three sets of repeated measure ANOVAs were used to examine changes in fear, state anxiety, and state dissociation across different phases of the study. Next, hierarchical multiple regressions were used to examine the effects of four pre-existing trauma-related characteristics (i.e., elapsed time since the most troublesome trauma, its related subclinical PTSD symptoms, trait anxiety, and trait dissociation) on cortisol and sAA at different phases among the individuals who had experienced at least one traumatic incident. As significant variance in cortisol levels has been associated with sex and age (e.g., Larsson, Gullberg, Råstam, & Lindblad, 2009), these two factors were entered in the first step, before the above-mentioned predictors in the second step, in order to control for their effects in the models. In the models predicting cortisol and sAA levels at the peri- and post-film phases, pre-film levels of the variables of interest were entered in the first step, in addition to sex and age, to account for the role of individual differences at baseline.

ECG data from the psychophysiological reactivity test were examined using VivoSense software (VivoNoetics, San Diego, CA, USA). Artifacts due to misdetected R-waves were easily recognized as outliers from the average HR curves and were manually deleted and interpolated using the software (Halligan, Michael, Wilhelm, Clark, & Ehlers, 2006). The participants with large amounts of ECG artifacts (i.e., more than 3% corrected R-R intervals; Hodson, Harnden, Roberts, Dennis, & Frayn, 2009; Vaile et al., 2001) were excluded from the analyses involving the CDR. A smaller sample size of 45 was hence involved in these analyses.

To classify participants with different patterns of CDR, Ward's hierarchical cluster analysis was used for its ability to produce clusters with similar numbers in small data sets (López et al., 2009; Milligan & Isaac, 1980). The variables used in this analysis are the second-by-second HR changes relative to baseline (15 s before the white noise) during the 20–45-s interval after the noise in the psychophysiological reactivity test (López et al., 2009).

After the classification, *t*-tests and a chi-square test were conducted to compare the demographic features (i.e., gender, age, years of education), BMI, and pre-existing characteristics between groups. Moreover, 2 (group: Accelerators vs. Decelerators) × 3 (time: pre- vs. peri- vs. post-film) mixed design ANOVAs were performed on cortisol and sAA. In all ANOVAs, homogeneity of variance was assessed by Levene's statistic, while sphericity was examined with Mauchly's test. When the assumption of sphericity was not met, the Greenhouse–Geisser corrected p values were reported.

Finally, another set of hierarchical multiple regressions were performed to examine the roles of CDR and sAA in the relationship between peri- and post-film cortisol levels and intrusive memory measures in the overall sample. Similar to the above-mentioned analyses, age, sex, and the pre-film levels of cortisol and sAA were controlled in the first step. Considering the potential impacts of prior trauma on cortisol levels (e.g., Resnick et al., 1995), a nominal variable, whether one had experienced a trauma in the past, was included in the first step as well. The levels of cortisol and sAA were included in the second step, as well as CDR, whereas the interactions between CDR and cortisol level, and between sAA and cortisol levels were entered in the third step, in order to examine potential moderating effects of sAA and CDR. When a significant predictive effect of an interaction term involving CDR was found, post hoc analyses were performed: Pearson's correlations were applied to examine the relationships between cortisol level and the intrusive memory measures separately among the Accelerators and Decelerators.

3. Results

3.1. State psychological and neuroendocrinological responses to the trauma film

Cortisol and sAA levels at different phases of the study are illustrated in Fig. 2 (related statistics are summarized in a later paragraph). One-way repeated measure ANOVAs suggested significant effects of time on fear ($F(2, 114) = 23.84$, $p < .001$, $\varepsilon = .85$), state anxiety ($F(2, 114) = 54.79$, $p < .001$) and state dissociation ($F(2, 114) = 7.48$, $p < .01$, $\varepsilon = .83$). The peri-film rating for fear was

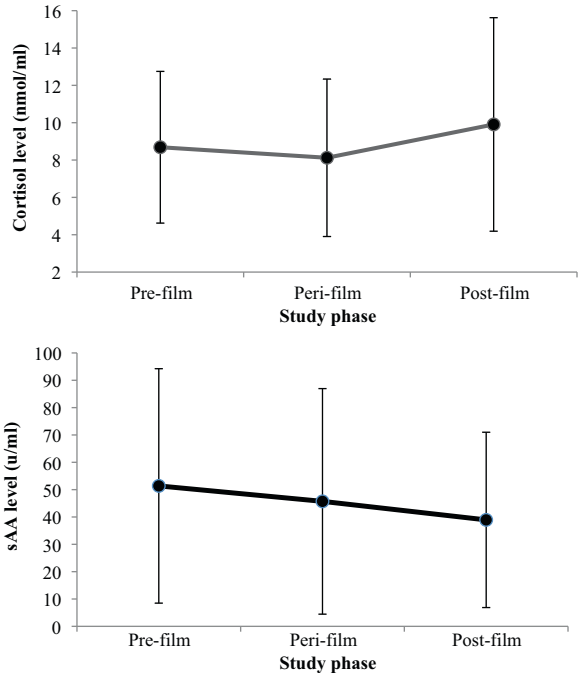

Fig. 2. Levels of salivary cortisol and alpha amylase across different phases of the study: error bars represent standard deviations.

significantly higher than the pre- and post-film phases ($p < .001$ for both). Peri-film state anxiety was significantly higher than pre- and post-film ($p < .001$ for both). Post-film state anxiety was higher than pre-film ($p < .001$). Moreover, state dissociation at the peri-film phase was higher than the pre- ($p < .01$) and post-film phases ($p < .001$).[1] Descriptive data for these psychological states, as well as for the intrusive memory measures, are summarized in Table 1. The mean compliance rating for the intrusion diary was 9.29 ($SD = 0.82$).

3.2. Previous trauma and psychological traits: their correlations with cortisol and sAA levels

Descriptive data for the psychological traits and trauma-related measures are summarized in Table 1.[2] On average, the participants experienced 1.16 types of trauma ($SD = 1.31$). Nineteen participants did not have any traumatic history. Among the rest who reported at least one trauma, the most stressful incident occurred on average 4.74 years ($SD = 1.27$) previously. The types of trauma experienced included: non-sexual assault by a stranger ($n = 26$), accident (except road traffic accident, $n = 21$), life-threatening illness of self or a loved one ($n = 12$), natural disaster ($n = 11$), non-sexual assault by an acquaintance ($n = 7$), sexual assault by a stranger ($n = 5$), sexual contact before age 18 by someone 5 or more years older ($n = 5$), imprisonment ($n = 2$), war ($n = 2$), and sexual assault by an acquaintance ($n = 1$).

Correlations between the trait/trauma-related measures (i.e., trait anxiety, trait dissociation, elapsed time since the most troublesome trauma, and its related subclinical PTSD symptoms), cortisol, and sAA levels at different phases are given in a supplementary table. To examine these factors' impacts on pre-film cortisol and sAA levels, hierarchical multiple regressions were performed, with age and sex entered in the first step, and these other predictors in the second step. The model did not significantly predict pre-film cortisol level (ΔR^2 of the first step = .01, $p = .78$; ΔR^2 of the second step = .10, $p = .52$). However, as shown in Table 2, the second step significantly increased the variance of baseline sAA level explained by the model. Higher trait dissociation and lower trait anxiety significantly predicted a lower baseline sAA level.

Supplementary table related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biopsycho.2014.08.002.

Similar hierarchical multiple regressions were applied to examine the effects of the above-mentioned variables on predicting cortisol and sAA levels at the peri- and post-film phases, with their baseline levels as additional fixed variables entered in the first step. As shown in Table 3, the elapsed time since trauma was found to be significantly predictive of peri-film cortisol level, with a more recent trauma predicting a lower level of cortisol peri-film. A consistent finding was evident in the model predicting post-film cortisol levels. Additionally, more severe subclinical PTSD symptoms were found to be predictive of lower post-film cortisol levels. Overall, the second step significantly increased the variance of post-film cortisol level explained. On the other hand, while peri- ($\Delta R^2 = .56$, $p < .001$) and post-film sAA levels ($\Delta R^2 = .82$, $p < .001$) were significantly predicted by pre-film sAA levels, entering the other predictors in the second step did not significantly increase the variances of peri- ($\Delta R^2 = .03$, $p = .66$) and post-film sAA levels ($\Delta R^2 = .02$, $p = .55$) explained by the models.

3.3. Categorization and group differences

To categorize participants based on the CDR, consistent with previous research (López et al., 2009), a three-cluster solution was first tested, but rejected for producing an imbalanced distribution of sample sizes. A two-cluster solution was then tested and resulted in two groups with equivalent sample sizes. Agreeing with the CDR literature (Eves & Gruzelier, 1984; López et al., 2009; Turpin & Siddle, 1978), a group of individuals showing a secondary peak of HR during the 20-to-45-s interval after the noise was identified (Accelerators: $n = 20$). The other group showing a HR decrease during this period was named Decelerators ($n = 25$; see Fig. 3). A 2 (group) × 26 (time: the 20- to 45-s interval) mixed design ANOVA found significant effects of group ($F(1, 44) = 45.50$, $p < .001$) and group by time interaction ($F(25, 1100) = 4.57$, $p < .001$, $\varepsilon = .21$) on HR. The time effect was nonsignificant ($F(25, 1100) = 2.02$, $p = .07$, $\varepsilon = .21$). These results indicated the efficacy of the above method in distinguishing individuals with different CDR.

The group differences in gender distribution (Accelerator: male = 12; Decelerator: male = 13, $X^2(1) = .42$, $p = .52$), age ($t(43) = 1.60$, $p = .12$), years in education ($t(42) = .69$, $p = .49$) and BMI ($t(43) = .33$, $p = .74$) were nonsignificant. Accelerators showed higher trait dissociation than Decelerators ($t(43) = -2.11$, $p < .05$). Group differences in trait anxiety ($t(42) = -.49$, $p = .63$) and subclinical PTSD symptoms ($t(32) = .16$, $p = .88$) were nonsignificant (see Table 1 for the descriptive data).

The 2 (group) × 3 (time: pre-, peri-, post-film) mixed design ANOVAs found significant main effects of time on cortisol ($F(2, 86) = 4.26$, $p < .05$, $\varepsilon = .66$) and sAA ($F(2, 86) = 6.84$, $p < .01$, $\varepsilon = .77$). Post-film cortisol level was significantly higher than peri-film ($p < .01$). Post-film sAA level was significantly lower than peri- ($p < .05$) and pre-film ($p < .001$). The effects of group and group by

[1] Pearson correlations showed that the frequency of intrusive memory was significantly and positively correlated with post-film fear ($r(57) = .42$, $p < .01$), peri- ($r(57) = .26$, $p < .05$) and post-film state anxiety ($r(57) = .40$, $p < .01$), as well as peri- ($r(57) = .39$, $p < .01$) and post-film state dissociation ($r(57) = .35$, $p < .01$). Moreover, the vividness of intrusive memory was significantly and positively correlated with peri- ($r(52) = .29$, $p < .05$) and post-film fear ($r(52) = .34$, $p < .05$), as well as peri-film anxiety ($r(52) = .31$, $p < .05$).

[2] Pearson's correlations were performed to examine the associations between trait anxiety, trait dissociation, subclinical PTSD symptoms, and the intrusive memory measures. None of these variables significantly predicted the frequency or vividness of intrusive memory (largest $r(54) = .23$, $p = .09$).

Table 1
Mean and standard deviations of physiological and psychological measures by phase and group.

	Overall sample		Accelerators		Decelerators	
	Mean	SD	Mean	SD	Mean	SD
Biological and background characteristics						
Age	24.33	4.45	23.65	4.06	25.88	5.08
Years in education	16.70	2.34	16.65	2.06	17.08	2.08
BMI (kg/m^2)	22.19	3.17	22.15	3.60	22.47	2.88
Psychological traits						
Trait anxiety (20–80)	38.27	10.54	39.89	8.04	38.36	11.82
Trait dissociation (%)	15.04	11.97	17.85	11.73	11.59	8.14
Subclinical PTSD symptoms (0–51)	4.49	5.36	4.00	4.20	5.22	6.68
Psychological states						
Pre-film fear (0–10)	1.65	1.88	1.35	1.50	1.89	2.12
Peri-film fear (0–10)	3.44	3.01	3.70	2.85	3.23	3.17
Post-film fear (0–10)	1.16	2.14	1.15	1.57	1.69	2.49
Pre-film state anxiety (20–80)	37.13	9.66	37.85	7.95	36.58	10.91
Peri-film state anxiety (20–80)	50.48	11.86	52.55	10.96	48.88	12.48
Post-film state anxiety (20–80)	42.15	12.81	42.50	12.22	41.88	13.47
Pre-film state dissociation (0–76)	5.76	5.52	7.25	5.92	4.62	5.00
Peri-film state dissociation (0–76)	8.74	8.02	10.70	7.93	7.23	7.91
Post-film state dissociation (0–76)	6.72	7.31	8.75	8.38	5.15	6.08
Cortisol levels (nmol/ml)						
Pre-film	8.69	4.06	8.66	3.86	8.42	4.63
Peri-film	8.12	4.22	7.56	2.81	8.06	4.85
Post-film	9.91	5.72	9.21	4.63	10.03	6.06
Alpha-amylase levels (u/ml)						
Pre-film	51.37	42.87	51.64	47.89	44.17	35.82
Peri-film	45.71	41.25	41.79	43.05	41.39	39.61
Post-film	38.94	32.07	33.76	33.54	37.82	33.51
Memory measures						
Intrusive memory						
Frequency_image	4.16	2.73	4.50	2.44	4.00	3.00
Vividness_image (0–10)	4.48	2.44	4.89	2.10	4.54	2.39

Note. BMI, body mass index; Frequency_image, frequency of imagery and mixed intrusion; Vividness_image, vividness of imagery and mixed intrusion.

Table 2
Multiple regressions predicting pre-film alpha-amylase level.

	B	SE *B*	*β*
Dependent variable: pre-film alpha-amylase level			
$\Delta R^2 = .01$, $p = .79$			
Constant	6.41	1.49	
Age	.32	.46	.12
Sex	.23	1.02	.04
$\Delta R^2 = .37$, $p < .01$			
Constant	6.62	1.56	
Age	−.17	.41	−.06
Sex	−.72	.91	−.12
Elapsed time since trauma	.16	.48	.05
Subclinical PTSD symptoms	1.14	.97	.18
Trait dissociation	−1.80	.47	−.62**
Trait anxiety	1.13	.48	.41*

* $p < .05$.
** $p < .01$.

time interaction on cortisol and sAA were nonsignificant (largest $F(2, 86) = 1.06$, $p = .34$, $\varepsilon = .77$). Similarly, group differences on the intrusive memory measures were nonsignificant (largest $t = -.60$, $p = .55$; see Table 1 for the descriptive data).

3.4. Biological predictors of intrusive memories

Hierarchical multiple regressions were used to examine the relationships between CDR, peri- and post-film sAA and cortisol levels, and the vividness of intrusions. Sex, age, whether one had experienced a trauma, as well as cortisol and sAA levels at the pre-film phase, were controlled in the first step. Next, peri- or post-film cortisol and sAA levels, as well as CDR were entered in the second step, followed by their interactions in the third step. The model including peri-film cortisol and sAA levels did not show a significant effect in predicting the vividness of intrusion (ΔR^2 in the

Table 3
Multiple regressions predicting peri-, and post-film cortisol levels.

	B	SE *B*	*β*
Dependent variable: peri-film cortisol level			
$\Delta R^2 = .56$, $p < .001$			
Constant	.70	.40	
Age	−.07	.07	−.12
Sex	−.02	.15	−.02
Pre-film cortisol level	1.52	.24	.74***
$\Delta R^2 = .09$, $p = .16$			
Constant	.78	.43	
Age	−.09	.07	−.16
Sex	−.09	.15	−.07
Pre-film cortisol level	1.64	.24	.80***
Elapsed time since trauma	.18	.08	.28*
Subclinical PTSD symptoms	−.19	.16	−.15
Trait dissociation	−.05	.08	−.08
Trait anxiety	.06	.08	.10
Dependent variable: post-film cortisol level			
$\Delta R^2 = .18$, $p = .07$			
Constant	1.19	.72	
Age	−.04	.12	−.05
Sex	.27	.26	.16
Pre-film cortisol level	1.12	.43	.41*
$\Delta R^2 = .22$, $p < .05$			
Constant	1.64	.73	
Age	−.09	.11	−.12
Sex	.10	.25	.06
Pre-film cortisol level	1.30	.41	.48**
Elapsed time since trauma	.30	.14	.36*
Subclinical PTSD symptoms	−.58	.27	−.33*
Trait dissociation	−.19	.13	−.23
Trait anxiety	.19	.13	.25

* $p < .05$.
** $p < .01$.
*** $p < .001$.

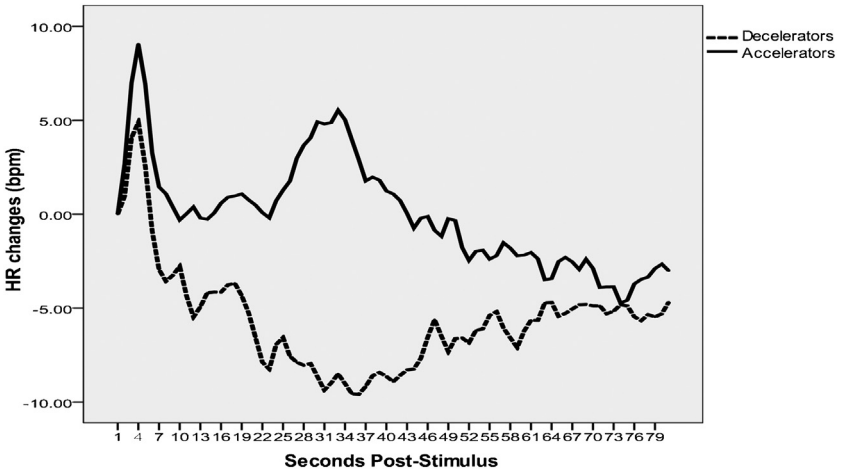

Fig. 3. Cardiac defense response by group.

first step = .20, $p = .15$; ΔR^2 in the second step = .08, $p = .37$; ΔR^2 in the third step = .03, $p = .48$). However, as summarized in Table 4, the model including cortisol and sAA levels at the post-film phase showed that younger age and lower post-film cortisol level were significantly predictive of higher vividness of intrusion.

Similar multiple regressions were used to predict the frequency of intrusion. As summarized in Table 5, peri-film cortisol level and its interaction with CDR significantly predicted the frequency of intrusion. To clarify the effect of the interaction term, correlations between peri-film cortisol and frequency of intrusion were conducted separately among the Accelerators and Decelerators. As shown in Fig. 4, a higher peri-film cortisol level significantly predicted more frequently occurring intrusions among the Accelerators ($r(20) = .53$, $p < .05$). However, the correlation between these two variables was nonsignificant among the Decelerators ($r(25) = -.04$, $p = .84$). In this final step lower levels of cortisol were associated with more intrusions, but the fact that this effect was not present at step 2 suggests it was an artificial consequence of including the interaction terms in the model.

Similarly, when cortisol and sAA levels at the post-film phase were examined (Table 6), a significant and negative correlation between post-film cortisol level and the frequency of intrusion was only found after the interaction terms were included in the model. The role of the interaction between cortisol level and CDR was replaced by a more dominant effect of the interaction between post-film cortisol and sAA levels at this stage. The results suggested a significant amplifying role of post-film sAA level in the correlation between post-film cortisol and the frequency of intrusion.

Table 4
Multiple regressions predicting vividness of intrusion with post-film cortisol, sAA levels and CDR.

	B	SE B	β
$\Delta R^2 = .20$, $p = .15$			
Constant	77.21	25.66	
Age	−5.78	3.20	−.29
Sex	−.53	7.33	−.01
Trauma	−11.06	8.28	−.22
Pre-film cortisol level	−17.10	9.61	−.28
Pre-film sAA level	2.40	10.76	.03
$\Delta R^2 = .21$, $p < .05$			
Constant	65.10	34.06	
Age	−6.89	3.04	−.35*
Sex	1.27	6.83	.03
Trauma	−6.42	7.59	−.13
Pre-film cortisol level	−2.92	9.75	−.05
Pre-film sAA level	−5.72	20.53	−.08
Post-film cortisol level	−11.70	3.56	−.51**
Post-film sAA level	3.06	6.41	.15
Cardiac defence response	−1.70	6.45	−.04
$\Delta R^2 = .00$, $p = .98$			
Constant	60.46	48.27	
Age	−6.80	3.18	−.34*
Sex	1.24	7.07	.03
Trauma	−6.21	8.10	−.12
Pre-film cortisol level	−2.89	10.39	−.05
Pre-film sAA level	−5.55	21.28	−.08
Post-film cortisol level	−9.87	12.99	−.43
Post-film sAA level	2.70	11.66	.13
Cardiac defence response	.85	15.63	.02
Post-film cortisol level × post-film sAA level	.64	28.90	.01
Post-film cortisol level × cardiac defence response	−2.39	13.33	−.10

* $p < .05$.
** $p < .01$.

Table 5
Multiple regressions predicting frequency of intrusion with peri-film cortisol, sAA levels and CDR.

	B	SE *B*	*β*
$\Delta R^2 = .09$, $p = .54$			
Constant	1.06	2.94	
Age	.40	.41	.16
Sex	.34	.87	.06
Trauma	−.51	.96	−.08
Pre-film cortisol level	1.81	1.15	.24
Pre-film sAA level	.44	1.32	.05
$\Delta R^2 = .03$, $p = .77$			
Constant	−.30	3.84	
Age	.41	.45	.16
Sex	.39	.93	.07
Trauma	−.68	1.00	−.11
Pre-film cortisol level	2.74	1.93	.37
Pre-film sAA level	−.07	1.97	−.01
Peri-film cortisol level	−.49	.76	−.17
Peri-film sAA level	.19	.66	.07
Cardiac defence response	.58	.90	.11
$\Delta R^2 = .14$, $p = .05$			
Constant	5.37	4.78	
Age	.29	.43	.11
Sex	.26	.88	.05
Trauma	−.20	.98	−.03
Pre-film cortisol level	2.09	1.84	.28
Pre-film sAA level	.25	1.87	.03
Peri-film cortisol level	−3.97	1.59	−1.40*
Peri-film sAA level	−1.52	1.24	−.55
Cardiac defence response	−3.20	2.15	−.59
Peri-film cortisol level × peri-film sAA level	2.48	1.42	.81
Peri-film cortisol level × cardiac defence response	3.23	1.58	1.19**

* $p < .05$.
** $p < .01$.

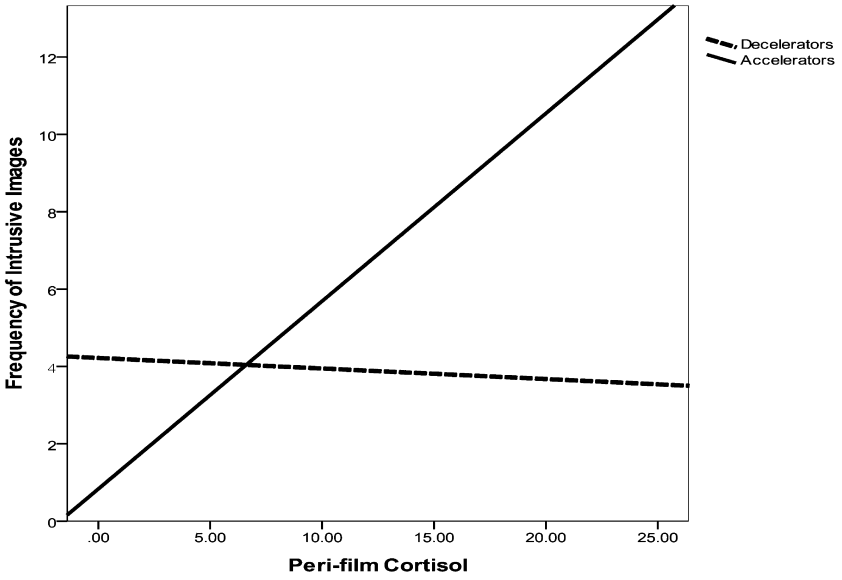

Fig. 4. Relationships between peri-film cortisol level and frequency of intrusive images by CDR group.

Table 6
Multiple regressions predicting frequency of intrusion with post-film cortisol, sAA levels and CDR.

	B	SE *B*	*β*
$\Delta R^2 = .09$, $p = .54$			
Constant	1.06	2.94	
Age	.40	.41	.16
Sex	.34	.87	.06
Trauma	−.51	.96	−.08
Pre-film cortisol level	1.81	1.15	.24
Pre-film sAA level	.44	1.32	.05
$\Delta R^2 = .04$, $p = .65$			
Constant	.89	4.48	
Age	.40	.44	.16
Sex	.58	.94	.11
Trauma	−.46	1.00	−.08
Pre-film cortisol level	2.22	1.33	.30
Pre-film sAA level	−.84	2.87	−.10
Post-film cortisol level	−.41	.51	−.14
Post-film sAA level	.46	.92	.17
Cardiac defence response	.69	.91	.13
$\Delta R^2 = .16$, $p < .05$			
Constant	−2.40	5.91	
Age	.37	.42	.15
Sex	.39	.88	.07
Trauma	.01	.97	.00
Pre-film cortisol level	1.52	1.28	.20
Pre-film sAA level	−1.90	2.70	−.22
Post-film cortisol level	−4.01	1.64	−1.39*
Post-film sAA level	−2.32	1.49	−.88
Cardiac defence response	−1.01	2.03	−.19
Post-film cortisol level × post-film sAA level	8.99	3.71	1.45*
Post-film cortisol level × cardiac defence response	1.91	1.72	.65

* $p < .05$.

4. Discussion

4.1. Psychological traits, trauma, subclinical PTSD symptoms and cortisol

The current study examined the role of cortisol and sAA levels as predictors of intrusive memories within the trauma film paradigm for the first time. Consistent with the literature (Takai et al., 2004), cortisol concentration increased due to the stressful nature of the trauma film. Unexpectedly, sAA concentration decreased. This may be because the trauma film, through which participants are required to sit still, tends to initiate passive coping strategies rather than fight/flight responses. A dissociative subtype of PTSD characterized by lowered HR and reduced amygdala responsiveness in the face of trauma reminders has been hypothesized (Lanius et al., 2010). Our data similarly indicate that trait dissociation is negatively correlated with sAA release in response to a traumatic stimulus. This finding confirms that the effects of dissociation are likely to be mediated at least in part by suppression of the SNS.

The data showed that whether one has experienced a trauma does not significantly affect resting or reactive cortisol levels. However, echoing studies finding an attenuating effect of prior trauma on cortisol (Delahanty et al., 2003; Ehring et al., 2008; Resnick et al., 1995), shorter elapsed time since the past trauma was found to be associated with lower cortisol levels peri- and post-film. Moreover, individuals with greater subclinical PTSD symptoms released less cortisol post-film. Overall, the results suggest that the impact of trauma should be taken into account in addition to its occurrence. Our findings also confirm under more tightly controlled experimental conditions than before that there is a negative correlation between the level of impact from prior trauma and the cortisol response to a later stressor.

4.2. Biological predictors of intrusive memories

As in previous studies of PTSD (van Zuiden et al., 2013), we did not find a clear-cut association between cortisol release and subsequent intrusive memories. However, consistent with the literature suggesting closer links between physiological arousal and subjective distress among Accelerators than Decelerators (Fergus, Rabenhorst, Orcutt, & Valentiner, 2011), a higher peri-film cortisol level was shown to predict more frequent intrusive images among the Accelerators, but not Decelerators. There were no overall group differences in number of intrusive memories, therefore CDR should not be seen as a risk factor, but as a marker of alterations in patterns of stress reactivity. The results highlighted the importance of individual differences in the effects of cortisol on involuntary trauma memory.

Additionally, echoing the effects on memory of noradrenergic activation found in animal studies (Roozendaal et al., 2006, 2002), sAA was found to moderate the relationship between the increase in post-film cortisol level and the frequency of intrusion.

The positive association between cortisol concentration and intrusion frequency was amplified among the individuals with higher sAA activity. The finding suggests that the facilitatory effect of cortisol on involuntary memory is more prominent when the SNS is simultaneously highly activated. Only one previous study has examined the effects of cortisol and sAA simultaneously, and has similarly found a synergistic effect of cortisol and alpha amylase on intrusive memories of picture stimuli following a cold pressor test (Bryant, McGrath, & Felmingham, 2013). Given that trait dissociation, a risk factor for intrusive memories, is related to lowered sAA levels in our data, the findings imply that different mechanisms may underlie the development of intrusion, particularly its frequency, among individuals with high and low trait dissociation. Similar evidence for alternative pathological mechanisms, one involving dissociation and one involving hyperarousal, have been reported in the PTSD literature (Andrews, Brewin, Stewart, Philpott, & Hejdenberg, 2009; Brewin, Andrews, Rose, & Kirk, 1999) and form part of the case for the introduction of a dissociative subtype.

4.3. Vividness of intrusions

The current study examined the vividness in addition to the frequency of intrusive images. Whereas the latter was a function of interactions between CDR, cortisol, and sAA, vividness was predicted by lower levels of post-film cortisol alone. The data support previous suggestions that low levels of cortisol post-trauma lead to the over-consolidation of traumatic memories (Yehuda & Harvey, 1997). Further, the discrepancy between the correlates of the vividness and frequency of intrusive memories suggests that they are distinct qualities affected by diverse mechanisms.

Specifically, two characteristics of cortisol have been studied: (1) as an objective indicator of stress, and (2) as a regulator of the consolidation-related neuromodulators. Based on our results, the frequency of intrusion is associated with the first characteristic, and therefore relates to stress intensity. On the other hand, the vividness of intrusion is associated with the second characteristic, and is a consequence of the interactions between cortisol and the neuromodulators. Both characteristics should be taken account, because they both cause clinical distress. Consider our finding of a negative association between previous traumatic impacts and cortisol reactivity to a later stressor, suggesting that less frequent intrusions may be found among individuals severely impacted from previous traumas. Their low cortisol level and less frequent intrusions do not necessarily imply minor distress. Contrastingly, their experience of vivid intrusions related to such insufficient cortisol secretion is of clinical concern.

These findings highlight the need for more sophisticated considerations in choosing measurements and interpreting results in this field. Moreover, while benefits of cortisol on treating and preventing PTSD have been suggested (Adinoff, Powell, & Greene, 2010; Bowirrat et al., 2010; Schelling et al., 2001, 2004), further considerations suggest these benefits will not be universal. Although an increase in cortisol is associated with decreased vividness, it is also related to more frequent intrusions in some individuals (i.e., accelerators).

4.4. Limitations and contributions

Generalization and interpretation of the current findings should be done with caution as we employed both an analog stimulus and a healthy population with relatively minor traumatic histories and subclinical PTSD symptoms. As is common in such studies, the intrusive memories present were relatively short-lived phenomena. Although there were striking parallels between processes observed in the PTSD literature and responses to the trauma film, we have no direct evidence that the processes we observed were identical to those seen in clinical conditions. Hence, clarification is needed before conclusions can be drawn regarding whether observations of the frequency and vividness of intrusions, or low cortisol secretion, are adaptive or pathological.

Second, the current sample size did not provide robust statistical power, given the numbers of variables involved in the analyses. Moreover, the phase of the menstrual cycle of our female participants was not taken into account. As menstrual cycles have been found to contribute to the stress responses of the HPA axis and its effects (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999), future studies with bigger sample sizes, as well as more sophisticated assessment and control for the phase of menstrual cycle, should be conducted.

Finally, although an 8-min resting period was present between the presentations of the startle triggering noise in the psychophysiological reactivity test and the trauma film, it is not known whether this was sufficient to dissipate away the effect of the former on the psychological and physiological responses to the latter. Moreover, the duration of time we measured cortisol levels (i.e., up to 12 min post-film) were relatively short. As the peak of stress-related cortisol increase is commonly found between 20 and 30 min after the exposure to stressors (e.g., Elzinga, Schmahl, Vermetten, van Dyck, & Bremner, 2003; La Marca et al., 2010), the profile shown in the current study might be somewhat incomplete. Therefore, replications are needed with counter-balancing of the psychophysiological reactivity test and the trauma film paradigm, as well as longer follow-up durations of cortisol measurement.

This was the first study to assess the role of sAA in the context of trauma and PTSD. The finding of low sAA during the trauma film and its correlation with trait dissociation suggest the involvement of passive coping mechanisms in the trauma film paradigm and the potential of using sAA as an index of prior vulnerability. The recentness of prior trauma and its associated subclinical symptoms were found to attenuate cortisol level during a later stressful situation. This provides independent support under controlled conditions for Yehuda and Harvey's hypothesis (1997)concerning the biological basis of vulnerability to PTSD. Moreover, the finding of moderating effects of the CDR and SNS on the relationship between the frequency of intrusion and cortisol highlights the importance of individual difference in psycho-physiological interactions that may help to explain why previous studies have found such diverse relationships between cortisol release and responses to trauma.

References

Adinoff, B., Powell, C. M., & Greene, R. (2010). Effects of exogenous glucocorticoid on combat-related PTSD symptoms. *Annals of Clinical Psychiatry*, *22*(4), 274–279.

Andrews, B., Brewin, C. R., Stewart, L., Philpott, R., & Hejdenberg, J. (2009). Comparison of immediate-onset and delayed-onset posttraumatic stress disorder in military veterans. *Journal of Abnormal Psychology*, *118*(4), 767–777. http://dx.doi.org/10.1037/a0017203

APA. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Publishing.

Bowirrat, A., Chen, T. J., Blum, K., Madigan, M., Bailey, J. A., Chen, A. L. C., et al. (2010). Neuro-psychopharmacogenetics and neurological antecedents of posttraumatic stress disorder: Unlocking the mysteries of resilience and vulnerability. *Current Neuropharmacology*, *8*(4), 335–358.

Bremner, J. D., Krystal, J. H., Putnam, F. W., Southwick, S. M., Marmar, C., Charney, D. S., & Mazure, C. M. (1998). Measurement of dissociative states with the clinician-administered dissociative states scale (CADSS). *Journal of Traumatic Stress*, *11*(1), 125–136. http://dx.doi.org/10.1023/A:1024465317902

Brewin, C. R., Andrews, B., Rose, S., & Kirk, M. (1999). Acute stress disorder and posttraumatic stress disorder in victims of violent crime. *American Journal of Psychiatry*, *156*(3), 360–366.

Bryant, R. A., McGrath, C., & Felmingham, K. L. (2013). The roles of noradrenergic and glucocorticoid activation in the development of intrusive memories. *PLOS ONE*, *8*(4), e62675. http://dx.doi.org/10.1371/journal.pone.0062675

Carlson, E. B., & Putnam, F. W. (1993). An update on the dissociative experiences scale. *Dissociation: Progress in the Dissociative Disorders*, *6*, 16–27.

Chou, C.-Y., La Marca, R., Steptoe, A., & Brewin, C. R. (2014). Heart rate, startle response, and intrusive trauma memories. *Psychophysiology*, *51*, 236–246. http://dx.doi.org/10.1111/psyp.12176

Delahanty, D. L., Raimonde, A. J., & Spoonster, E. (2000). Initial posttraumatic urinary cortisol levels predict subsequent PTSD symptoms in motor vehicle accident victims. *Biological Psychiatry*, *48*(9), 940–947. http://dx.doi.org/10.1016/S0006-3223(00)00896-9

Delahanty, D. L., Raimonde, A. J., Spoonster, E., & Cullado, M. (2003). Injury severity, prior trauma history, urinary cortisol levels, and acute PTSD in motor vehicle accident victims. *Journal of Anxiety Disorders*, *17*(2), 149–164. http://dx.doi.org/10.1016/S0887-6185(02)00185-8

Delgado, L. C., Guerra, P., Perakakis, P., Mata, J. L., Pérez, M. N., & Vila, J. (2009). Psychophysiological correlates of chronic worry: Cued versus non-cued fear reaction. *International Journal of Psychophysiology*, *74*(3), 280–287. http://dx.doi.org/10.1016/j.ijpsycho.2009.10.007

Dressendörfer, R., Kirschbaum, C., Rohde, W., Stahl, F., & Strasburger, C. (1992). Synthesis of a cortisol-biotin conjugate and evaluation as a tracer in an immunoassay for salivary cortisol measurement. *Journal of Steroid Biochemistry and Molecular Biology*, *43*(7), 683–692. http://dx.doi.org/10.1016/0960-0760(92)90294-S

Dubester, K. A., & Braun, B. G. (1995). Psychometric properties of the dissociative experiences scale. *Journal of Nervous and Mental Disease*, *183*(4), 231–235. http://dx.doi.org/10.1097/00005053-199504000-00008

Ehring, T., Ehlers, A., Cleare, A. J., & Glucksman, E. (2008). Do acute psychological and psychobiological responses to trauma predict subsequent symptom severities of PTSD and depression? *Psychiatry Research*, *161*(1), 67–75. http://dx.doi.org/10.1016/j.psychres.2007.08.014

Elzinga, B. M., Schmahl, C. G., Vermetten, E., van Dyck, R., & Bremner, J. D. (2003). High cortisol levels following exposure to traumatic reminders in abuse-related PTSD. *Neuropsychopharmacology*, *28*, 1656–1665.

Eves, F. F., & Gruzelier, J. H. (1984). Individual differences in the cardiac response to high intensity auditory stimulation. *Psychophysiology*, *21*(3), 342–352. http://dx.doi.org/10.1111/j.1469-8986.1984.tb02946.x

Fergus, T. A., Rabenhorst, M. M., Orcutt, H. K., & Valentiner, D. P. (2011). Reactions to trauma research among women recently exposed to a campus shooting. *Journal of Traumatic Stress*, *24*(5), 596–600. http://dx.doi.org/10.1002/jts.20682

Fernández, M. C., & Vila, J. (1989). Cognitive versus motivational significance of the cardiac response to intense auditory stimulation. *International Journal of Psychophysiology*, *8*, 49–59. http://dx.doi.org/10.1016/0167-8760(89)90010-6

Foa, E. B. (1995). *Posttraumatic stress diagnostic scale manual*. Minneapolis, MN: National Computer System.

Foa, E. B., Cashman, L., Jaycox, L., & Perry, K. (1997). The validation of a self-report measure of posttraumatic stress disorder: The Posttraumatic Diagnostic Scale. *Psychological Assessment*, *9*(4), 445–451. http://dx.doi.org/10.1037//1040-3590.9.4.445

Halligan, S. L., Michael, T., Wilhelm, F. H., Clark, D. M., & Ehlers, A. (2006). Reduced heart rate responding to trauma reliving in trauma survivors with PTSD: Correlates and consequences. *Journal of Traumatic Stress*, *19*(5), 721–734. http://dx.doi.org/10.1002/jts.20167

Het, S., Ramlow, G., & Wolf, O. (2005). A meta-analytic review of the effects of acute cortisol administration on human memory. *Psychoneuroendocrinology*, *30*(8), 771–784. http://dx.doi.org/10.1016/j.psyneuen.2005.03.005

Hodson, L., Harnden, K., Roberts, R., Dennis, A., & Frayn, K. (2009). Does the DASH diet lower blood pressure by altering peripheral vascular function? *Journal of Human Hypertension*, *24*(5), 312–319. http://dx.doi.org/10.1038/jhh.2009.65

Holmes, E. A., & Bourne, C. (2008). Inducing and modulating intrusive emotional memories: A review of the trauma film paradigm. *Acta Psychologica*, *127*(3), 553–566. http://dx.doi.org/10.1016/j.actpsy.2007.11.002

Holmes, E. A., Brewin, C. R., & Hennessy, R. G. (2004). Trauma films, information processing, and intrusive memory development. *Journal of Experimental Psychology-General*, *133*(1), 3–22. http://dx.doi.org/10.1037/0096-3445.133.1.3

Kirschbaum, C., Kudielka, B. M., Gaab, J., Schommer, N. C., & Hellhammer, D. H. (1999). Impact of gender, menstrual cycle phase, and oral contraceptives on the activity of the hypothalamus-pituitary-adrenal axis. *Psychosomatic Medicine*, *61*(2), 154–162.

Klaassens, E. R., Giltay, E. J., Cuijpers, P., van Veen, T., & Zitman, F. G. (2012). Adulthood trauma and HPA-axis functioning in healthy subjects and PTSD patients: A meta-analysis. *Psychoneuroendocrinology*, *37*(3), 317–331. http://dx.doi.org/10.1016/j.psyneuen.2011.07.003

La Marca, R., Waldvogel, P., ThÖrn, H., Tripod, M., Wirtz, P. H., Pruessner, J. C., et al. (2010). Association between cold face test-induced vagal inhibition and cortisol response to acute stress. *Psychophysiology*, *10*, 1–10.

Lanius, R. A., Vermetten, E., Loewenstein, R. J., Brand, B., Schmahl, C., Bremner, J. D., et al. (2010). Emotion modulation in PTSD: Clinical and neurobiological evidence for a dissociative subtype. *American Journal of Psychiatry*, *167*(6), 640–647. http://dx.doi.org/10.1176/1ppi.1jp.2009.09081168

Larsson, C. A., Gullberg, B., Råstam, L., & Lindblad, U. (2009). Salivary cortisol differs with age and sex and shows inverse associations with WHR in Swedish women: A cross-sectional study. *BMC Endocrine Disorders*, *9*, 16. http://dx.doi.org/10.1186/1472-6823-9-16

Lazarus, R. S., Opton, E. M., Nomikos, M. S., & Rankin, N. O. (1965). The principle of short-circuiting of threat: Further evidence 1. *Journal of Personality*, *33*(4), 622–635. http://dx.doi.org/10.1111/j.1467-6494.1965.tb01408.x

López, R., Poy, R., Pastor, M. C., Segarra, P., & Moltó, J. (2009). Cardiac defense response as a predictor of fear learning. *International Journal of Psychophysiology*, *74*(3), 229–235. http://dx.doi.org/10.1016/j.ijpsycho.2009.09.006

McFarlane, A. C., Atchison, M., & Yehuda, R. (1997). The acute stress response following motor vehicle accidents and its relation to PTSD. *Annals of the New York Academy of Sciences*, *821*(1), 437–441. http://dx.doi.org/10.1111/j.1749-6632.1997.tb48299.x

Metzger, R. L. (1976). A reliability and validity study of the State-Trait Anxiety Inventory. *Journal of Clinical Psychology*, *32*, 276–278. http://dx.doi.org/10.1002/1097-4679(197604)32:2<276::AID-JCLP2270320215>3.0.CO;2-G

Milligan, G. W., & Isaac, P. D. (1980). The validation of four ultrametric clustering algorithms. *Pattern Recognition*, *12*(2), 41–50. http://dx.doi.org/10.1016/0031-3203(80)90001-1

Nater, U. M., Rohleder, N., Schlotz, W., Ehlert, U., & Kirschbaum, C. (2007). Determinants of the diurnal course of salivary alpha-amylase. *Psychoneuroendocrinology*, *32*(4), 392–401. http://dx.doi.org/10.1016/j.psyneuen.2007.02.007

Resnick, H. S., Yehuda, R., Pitman, R. K., & Foy, D. W. (1995). Effect of previous trauma on acute plasma cortisol level following rape. *American Journal of Psychiatry*, *152*, 1675–1677.

Richards, M., & Eves, F. F. (1991). Personality, temperament and the cardiac defense response. *Personality and Individual Differences*, *12*(10), 999–1007. http://dx.doi.org/10.1016/0191-8869(91)90030-F

Robles Ortega, H., Marfil, N., & Reyes del Paso, G. (1995). Hostility, type A behavioral pattern and cardiac reactivity of Type A/B subjects. *Estudios de Psicologia*, *53*, 65–88. http://dx.doi.org/10.1174/021093995321237176

Rohleder, N., Nater, U. M., Wolf, J. M., Ehlert, U., & Kirschbaum, C. (2004). Psychosocial stress-induced activation of salivary alpha-amylase: An indicator of sympathetic activity? *Annals of the New York Academy of Sciences*, *1032*(1), 258–263. http://dx.doi.org/10.1196/annals.1314.033

Roozendaal, B., Okuda, S., de Quervain, D. J., & McGaugh, J. L. (2006). Glucocorticoids interact with emotion-induced noradrenergic activation in influencing different memory functions. *Neuroscience*, *138*(3), 901–910. http://dx.doi.org/10.1016/j.neuroscience.2005.07/049

Roozendaal, B., Quirarte, G. L., & McGaugh, J. L. (2002). Glucocorticoids interact with the basolateral amygdala β-adrenoceptor–cAMP/cAMP/PKA system in influencing memory consolidation. *European Journal of Neuroscience*, *15*(3), 553–560. http://dx.doi.org/10.1046/j.0953-816x.2001.01876.x

Ruiz-Padial, E., Mata, J. L., Rodríguez, S., Fernández, M. C., & Vila, J. (2005). Non-conscious modulation of cardiac defense by masked phobic pictures. *International Journal of Psychophysiology*, *56*(3), 271–281. http://dx.doi.org/10.1016/j.ijpsycho.2004.12.010

Schelling, G., Briegel, J., Roozendaal, B., Stoll, C., Rothenhäusler, H.-B., & Kapfhammer, H.-P. (2001). The effect of stress doses of hydrocortisone during septic shock on posttraumatic stress disorder in survivors. *Biological Psychiatry*, *50*(12), 978–985. http://dx.doi.org/10.1016/S0006-3223(01)01270-7

Schelling, G., Kilger, E., Roozendaal, B., de Quervain, D. J.-F., Briegel, J., Dagge, A., et al. (2004). Stress doses of hydrocortisone, traumatic memories, and symptoms of posttraumatic stress disorder in patients after cardiac surgery: A randomized study. *Biological Psychiatry*, *55*(6), 627–633.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the state-trait anxiety inventory form Y*. Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1989). . *State-trait anxiety inventory: Bibliography* (Vol. 2) Palo Alto, CA: Consulting Psychologists Press.

Spitzer, R. L., Williams, J. B. W., Gibbon, M., & First, M. B. (1990). Structured Clinical Interview for DSM-III-R Patient ed. Washington, D.C.: American Psychiatric Press.

Tabachnick, B. G., & Fidell, L. S. (1996). . *Using multivariate statistics* (Vol. 3) New York: Harper Collins.

Takai, N., Yamaguchi, M., Aragaki, T., Eto, K., Uchihashi, K., & Nishikawa, Y. (2004). Effect of psychological stress on the salivary cortisol and amylase levels in healthy young adults. *Archives of Oral Biology*, *49*(12), 963–968. http://dx.doi.org/10.1016/j.archoralbio.2004.06.007

Turpin, G., & Siddle, D. (1978). Cardiac and forearm plethysmographic responses to high intensity auditory stimulation. *Biological Psychology*, *6*(4), 267–281. http://dx.doi.org/10.1016/0301-0511(78)90029-7

Vaile, J., Chowdhary, S., Osman, F., Ross, H., Fletcher, J., Littler, W., et al. (2001). Effects of angiotensin II (AT1) receptor blockade on cardiac vagal control in heart failure. *Clinical Science*, *101*(6), 559–566.

van Zuiden, M., Kavelaars, A., Geuze, E., Olff, M., & Heijnen, C. J. (2013). Predicting PTSD: Pre-existing vulnerabilities in glucocorticoid-signaling and implications for preventive interventions. *Brain, Behavior, and Immunity*, *30*, 12–21. http://dx.doi.org/10.1016/j.bbi.2012.08.015

Vila, J., Fernández, M. C., & Godoy, J. (1992). The cardiac defense response in humans: Effect of stimulus modality and gender differences. *Journal of Psychophysiology*, *6*, 140–154.

Yehuda, R., & Harvey, P. (1997). Relevance of neuroendocrine alterations in PTSD to memory-related impairments of trauma survivors. In R. Lindsay (Ed.), *Recollection of trauma* (pp. 221–252). New York: Plenum.